A BRAIN WITH COMPLETE ABSENCE OF THE CORPUS CALLOSUM.

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I AM indebted to Professor Young for having kindly placed at my disposal the brain which forms the subject of this communication. The specimen has lain in the Anatomy Department of the University of Manchester for several years with the membranes intact, so that the records of the case have been unfortunately entirely lost. The brain was handed over to two of the students for dissection, the absence of the corpus callosum not being detected until the upper part of the left hemisphere had been removed. On a superficial study the specimen exhibited no exceptional features beyond those usually associated with deficiency of the corpus callosum. A closer examination of the limbic lobe, however, disclosed several interesting features which were considered worthy of being placed on record.

In a certain proportion of the cases of absence of the corpus callosum, the deficiency has been only a partial one. Thus, of the thirty cases published up to 1888, Bruce (2) found that entire absence occurred only in fifteen of these. In the case at present under consideration the corpus callosum was completely absent.

The main interest in this specimen is centred in the commissural structures which are developed in association with the lamina terminalis. Thus, in addition to the absence of the corpus callosum, the two lateral halves of the fornix are not united together by transverse commissural fibres, but are merely connected by an exceedingly thin semi-transparent membrane. The "fore-and-aft" fibres of the fornix are therefore alone represented. The posterior pillars pass to the uncus as usual. The anterior pillars, however, show a difference of arrangement on the two sides. For example, on the right side, by far the greater number of the fibres pass in front of the anterior commissure, very few coursing posteriorly to this structure. On the left side, most of the fibres go behind the commissure, though a considerable number pass in front (fig. 4). The corpora mammillaria are well formed on both sides.

From the outer margin of the band of fibres representing each lateral half of the body of the fornix there is an extension outwards of the thin membranous sheet already referred to (fig. 3). This can be readily traced to its termination by blending with the cortex of the callosal convolution at the bottom of what corresponds to the callosal sulcus (fig. 4). It accordingly represents the *lamina terminalis.* When traced forwards in the middle line it blends with the anterior commissure (fig. 2). From the latter structure it passes downwards as the lamina cinerea, which is connected as usual with the optic commissure (fig. 2). The lamina has thus retained its embryonic attachments in this specimen.

Two other longitudinal or "fore-and-aft" systems of fibres run close to

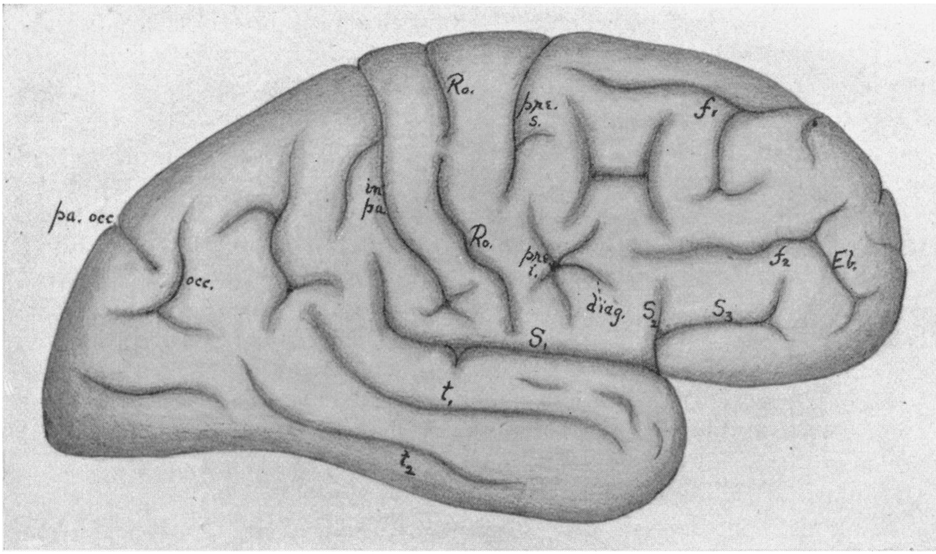

FIG. 1.—Outer surface of right hemisphere (three-fifths natural size).

the outer side of the fornix, lying more or less parallel to the latter. The band of fibres next to the fornix, when traced anteriorly, blends with the precommissural fibres of the anterior pillar, more particularly on the right side, the resultant band passing across the anterior perforated spot to the uncus and the temporal pole. Some of the fibres can also be followed to the mesial olfactory root (figs. 2 and 3). Posteriorly, this second system of longitudinal fibres remains distinct from the posterior pillar of the fornix, though it overlaps the latter slightly (fig. 2). It can be traced to its junction with the posterior extremity of the dentate convolution, the latter structure being more prominently developed than usual. This band, from its anterior and posterior connections, represents the *striæ longitudinales* (both mesial and lateral). The band of Giacomini is only faintly discernible.

The third or most externally placed band of fibres lies close to the line of junction of the lamina with the callosal convolution. It passes anteriorly to the anterior perforated spot, on the surface of which it gradually becomes lost. At its posterior extremity it becomes intimately associated with the longitudinal striæ (fig. 3). This close connection does not exist long, however, for the united band soon bifurcates again into its two constituent elements, those fibres belonging to this outer set ending in the hippocampal convolution close to the isthmus (figs. 2 and 3). The attachments of this

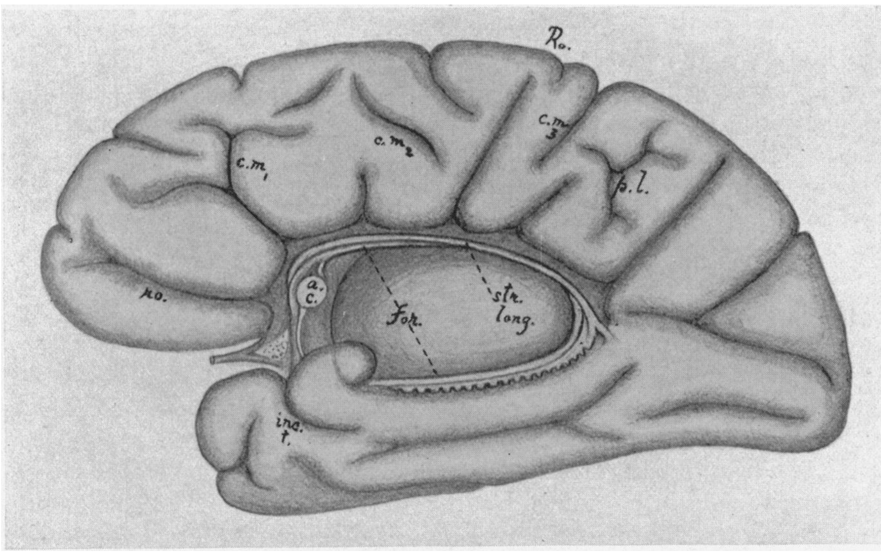

FIG. 2.—Mesial surface of right hemisphere (three-fifths natural size).

outer band correspond to those of the *cingulum*, which structure it apparently represents.

The tissue intervening between these three groups of longitudinal fibres is thin and translucent, and apparently almost devoid of nervous elements. That portion connecting the two halves of the fornix was so delicate that most of it came away with the pia mater. The remains could, however, be recognised as a ragged fringe attached to the inner margins of the fornix bands, which floated out on immersing the brain in fluid (fig. 3).

This intimate association of the fornix, longitudinal striæ, and cingulum with the lamina terminalis[1] suggests that in this case they had all been

[1] The employment of this term for the adult brain is, I think, justifiable in the present specimen.

developed in that structure. The close relationship which the fornix bears to the lamina has been pointed out by Elliot Smith (15 *et seq.*). A difficulty arises, however, in regard to the genesis of the longitudinal striæ and cingulum. The usual acceptation is that the former represent part of an aborted convolution belonging to the limbic lobe (14). The intimate relationship which the longitudinal striæ bear to the fornix in this specimen has, however, led me to accept Cunningham's suggestion (3 and 4), that these striæ are simply an outlying part of the fornix system. Both striæ and fornix, it may be noted, normally contain a system of longitudinal fibres *plus* a certain amount of grey matter. Thus, in some monkeys there is a band of grey matter running along the upper surface of the fornix, forming the so-called *gyrus infracallosus* (14), while the thin lamina of grey matter in relation to the striæ is continuous with the grey matter of the callosal gyrus. Zuckerkandl (22 and 23) for this reason regarded these striæ, together with their grey matter, as a degenerate convolution (*gyrus supracallosus*). When Zuckerkandl gave effect to this acceptation of the nature of these striæ, the lamina terminalis of His (10) had not received the recognition now so freely accorded to it, so that another explanation of the presence of the above grey matter is possible in the light of our present knowledge of this embryonic structure. Thus, if the lamina terminalis of a typical mammalian embryo (*e.g.* rabbit of the 13th day) be studied, it will be found to be as richly endowed with neuroblasts as the neighbouring hemisphere wall, the structural appearance being exactly similar in both. One can readily trace the separation of the cell-elements in the lamina terminalis into groups by the development of the commissural systems. As a result of recent work in this direction, I am convinced that the grey matter in association with the striæ and fornix is derived from the lamina terminalis, and not introduced from any external source. This question will be fully discussed in a future communication.

The close association of the fibres of the cingulum with the striæ in this specimen tempts one to include this band also as an outlying part of the fornix system. It certainly appears in this instance to be an intimate part of the lamina terminalis, a fact which is suggestive of its origin in the latter. The discussion of this question will likewise have to be postponed for the present.

It is of interest to note that absence or deficiency of the corpus callosum is apparently associated with absence also of the septum lucidum. At least this has been so in the cases recently recorded by Douglas-Crawford (6), Elliot Smith [1] and Patten.[1] Bruce (2), however, in his specimen figures an area which he regards as representing the septum lucidum. The

[1] Exhibited at the Summer Meeting of the Anatomical Society, May 1906.

septum proved to be absent in the present case also. This fact will be found of great significance when considered in association with the development of the septum lucidum, as will be brought out more fully in a subsequent paper.

The probable course of development in this specimen is best appreciated by a study of the developing fore-brain, both in animals which possess a corpus callosum, and in those (such as birds) in which this commissure is absent. In the human embryo, as in lower animals, the roof-plate of the

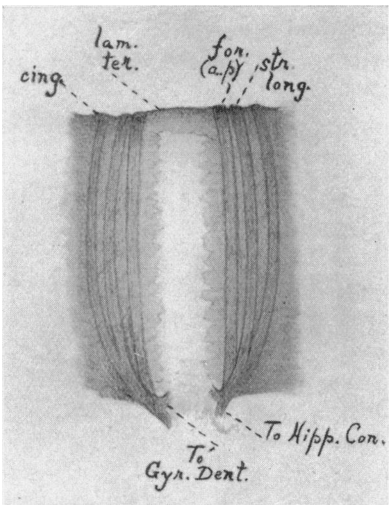

Fig. 3.—Arrangement of longitudinal bands in lamina terminalis.

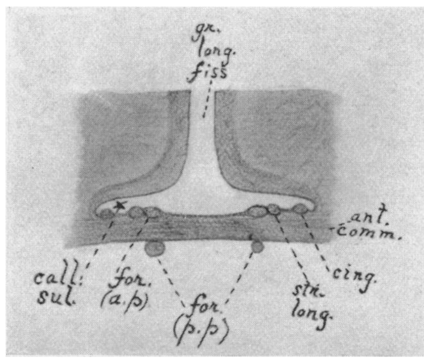

Fig. 4.—Horizontal section through anterior commissure and great longitudinal fissure.

fore-brain, in front of the epiphysis and superior commissure, becomes a simple epithelial structure as far forward in the middle line as the lamina terminalis. Practically the whole of this epithelial roof becomes invaginated to form the covering of the velum interpositum.[1] In birds (*e.g.* the chick) this epithelial transformation of the cerebral roof-plate goes a distinct step further. The epithelial transformation has been very extensive in this specimen, for it has occurred as far forward in the middle line as the anterior commissure (fig. 2), so that we have here a reversion to a lower type of development, involving not only the fore-brain roof-plate, but also a considerable part of the lamina terminalis.

Douglas-Crawford (6) has furnished a full account of the convolutions in his case. I shall therefore be content to refer to a few points of special

[1] The *paraphysis* is developed from this roof in front of the velum.

interest. In the present specimen the convolutions and sulci were studied to best advantage on the right side, owing to the upper part of the left hemisphere having been removed before the condition was recognised. They do not exhibit to any marked degree the radiating arrangement which has been described by Cunningham (3 and 4) in brains with absence of the corpus callosum. The most prominent features are the simple arrangement of the convolutions, as also the number and fantastic shape of certain isolated sulci, especially on the outer surface. Two of the latter are particularly prominent, and are H-shaped. One is in the right middle frontal gyrus, and the other in the parietal lobe immediately above the tail of the right parallel fissure (fig. 1). Another sulcus, exhibiting striking

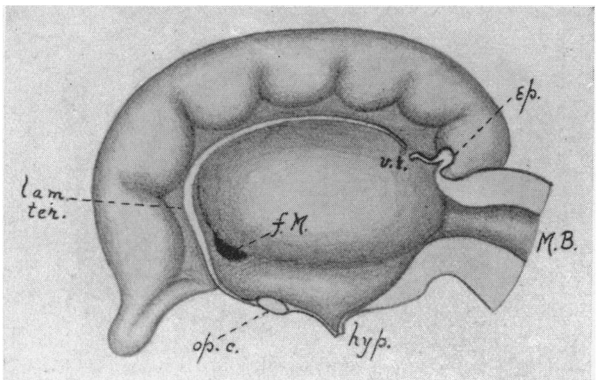

FIG. 5.—Mesial aspect of right hemisphere of 6·5 cm. fœtus (enlarged 2½ times).

features, is situated in front of the lower part of the right fissure of Rolando, and consists of a group of five radiating sulci. When examined carefully it may be recognised as consisting of the inferior precentral sulcus blended with the diagonal sulcus. The right fissure of Rolando consists of an upper and a lower limb. The vertical part of the intraparietal sulcus is unusually extensive, and is continuous round the superior border with a sulcus on the mesial aspect to be subsequently described.

The limiting sulcus of Reil is deeper than usual, while the gyri of the insula are prominently marked.

The sulci on the mesial aspect of the hemisphere possess a radiating arrangement, as described by Douglas-Crawford (6) and Bruce (2). It is interesting to compare these with the sulci in the same region of the fœtal brain, as Bruce (2) has previously done (figs. 2 and 5). It will be found that, prior to any great advance in the formation of the corpus callosum, the so-called temporary sulci are arranged in a radiating fashion. Fig. 5

shows the appearance presented by the mesial aspect of the right hemisphere of a 6·5 cm. human fœtus. By the end of the sixth month the corpus callosum has become well developed, the mesial surface of the hemisphere as a result tending to be compressed between the corpus callosum and the cranial vault. This causes obliteration of these temporary radial sulci, and the formation of a fresh set of sulci which lie more or less parallel to these opposing surfaces. The calloso-marginal sulcus is one of the most important of these permanent sulci, and is usually developed in three parts—anterior, middle, and posterior (13). These are shown in fig. 6, which is the mesial aspect of the hemisphere of a fœtus at the end of the sixth month. On turning to the specimen (fig. 2), one can recognise the effect of the absence or deficiency of one of the forces causing the com-

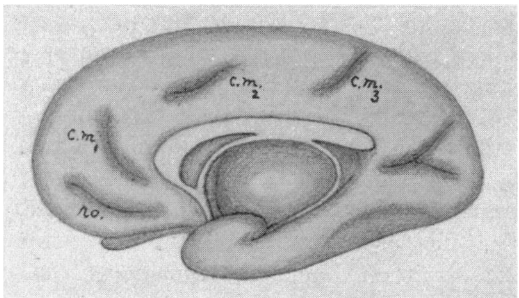

FIG. 6.—Mesial aspect of right hemisphere (fœtus at end of sixth month).

pression of the mesial surface of the growing hemisphere referred to above. There is the suggestion of an attempt at forming the anterior and middle portions of the calloso-marginal sulcus ($c.m._1$ and $c.m._2$). The upper part of the radial sulcus lettered $c.m._3$ is in the site of the posterior portion of the calloso-marginal sulcus; but one cannot state definitely whether or not this represents the posterior extremity of the permanent fissure. This radial sulcus is continuous round the mesial border of the hemisphere with the upper end of the intraparietal sulcus, the two together forming a very extensive fissure. The rostral sulcus will be observed to be well developed, while the incisura temporalis is particularly prominent (fig. 2). The calcarine and internal parieto-occipital fissures appear in fig. 2 to be in direct continuity; but on opening them up the gyrus cunei was found just within, and therefore almost level with the surface. In Crawford's case (6) the gyrus cunei comes to the surface, and separates the above fissures—a condition which, indeed, appears to be usually found in brains with absence of the corpus callosum.

The whole of the rhinencephalon is unusually well developed, so that the roots of the olfactory peduncle can be traced with ease to their respective destinations. It is rather interesting to note that this undue prominence of the rhinencephalon is associated with entire absence of the transverse commissural fibres of the fornix, a fact which suggests that these fibres do not form a very important, far less an essential, part of the rhinencephalon.

The cerebral sulci are on the whole deeper than in normal brains, the average being 14 or 15 mm. instead of the normal 10–12 mm. (12). Some are exceptionally deep. Thus the lower segment of the right Rolandic fissure is 20 mm. deep at its middle, while the depth of the post-central sulcus is as much as 21 mm.

Absence of the corpus callosum is usually found associated with a tendency to abnormal size of the ventricular cavities, almost amounting to a hydrocephalic condition. Indeed, Turner (21) has suggested that this may explain the arrested development of the corpus callosum. In the present specimen, in addition to a complete failure of those fibres of the corpus callosum which cross the mesial plane, there is apparently almost total absence of those portions of the commissure which, under normal conditions, occupy each hemisphere and constitute the roof of the lateral ventricles. Consequently the latter cavities are decidedly more capacious than normal. The increased capacity, from this point of view, is thus, partly at least, the result of a general deficiency of the corpus callosum; though this conclusion does not entirely put out of court the possible existence of a concomitant hydrocephalic condition.

LITERATURE CONSULTED.

(1) Beevor, C. E., "On the Course of the Fibres of the Cingulum, and the Posterior Parts of the Corpus Callosum and Fornix, in the Marmoset Monkey," *Phil. Trans. Roy. Soc.*, vol. clxxxii. B, 1891.

(2) Bruce, Alex., "On the Absence of the Corpus Callosum in the Human Brain," *Proc. Roy. Soc. Edin.*, vol. xv., 1888; also in *Brain*, vol. xii., 1889–90.

(3) Cunningham, D. J., "The Complete Fissures of the Human Cerebrum, and their Significance in Connection with the Growth of the Hemisphere and the Appearance of the Occipital Lobe," *Jour. Anat. and Phys.*, vol. xxiv., 1890.

(4) Cunningham, D. J., "The Surface Anatomy of the Primate Cerebrum," *Cunningham Memoirs of the Royal Irish Academy*, No. 7, 1890–92.

(5) Cunningham, D. J., *Text-book of Anatomy*, 1st ed., 1902, p. 531.

(6) Douglas-Crawford, D., "A Case of Absence of the Corpus Callosum," *Jour. Anat. and Phys.*, vol. xl., 1906.

(7) Hamilton, D. J., "On the Corpus Callosum in the Human Brain," *Jour. Anat. and Phys.*, vol. xix., 1885.

(8) HAMILTON, D. J., "On the Corpus Callosum in the Embryo," *Brain*, vol. viii., 1885–86.

(9) HILL, ALEX., "The Cerebrum of *Ornithorhynchus paradoxus*," *Phil. Trans. Roy. Soc.*, vol. clxxxiv. B, 1893.

(10) HIS, WM., *Anatomie menschlicher Embryonen*, Leipzig.

(11) OSBORN, F., "The Origin of the Corpus Callosum: a Contribution upon the Cerebral Commissures of the Vertebrata" (two parts), *Morph. Jahrbuch*, Bd. xii., 1887.

(12) *Quain's Anatomy*, vol. iii., part 1, 10th ed., 1895, p. 137.

(13) *Ibid.*, p. 145.

(14) *Ibid.*, p. 158.

(15) SMITH, G. ELLIOT, "The Fornix Superior," *Jour. Anat. and Phys.*, vol. xxxi., 1897.

(16) SMITH, G. ELLIOT, "The Relation of the Fornix to the Margin of the Cerebral Cortex," *Jour. Anat. and Phys.*, vol. xxxii., 1898.

(17) SMITH, G. ELLIOT, "Further Observations upon the Fornix," *Jour. Anat. and Phys.*, vol. xxxii., 1898.

(18) SMITH, G. ELLIOT, "The Origin of the Corpus Callosum: a Comparative Study of the Hippocampal Region of the Cerebrum of Marsupialia and certain Cheiroptera," *Trans. Linn. Soc. Lond.*, vol. vii., part 3, 1897.

(19) SMITH, G. ELLIOT, "Further Observations on the Anatomy of the Brain in the Monotremata," *Jour. Anat. and Phys.*, vol. xxxiii., 1899.

(20) SYMINGTON, J., "The Cerebral Commissures in the Marsupialia and Monotremata," *Jour. Anat. and Phys.*, vol. xxvii., 1893.

(21) TURNER, Sir WM., "A Human Cerebrum imperfectly divided into two Hemispheres," *Jour. Anat. and Phys.*, vol. xii., 1878.

(22) ZUCKERKANDL, E., *Ueber das Riechcentrum*, Stuttgart, 1887.

(23) ZUCKERKANDL, E., "Ueber das Riechbündel des Cornu Ammonis," *Anat. Anz.*, Bd. iii., 1889.

ABBREVIATIONS.

a.c. anterior commissure.
ant.comm. anterior commissure.
call.sul. callosal sulcus.
$c.m._1$, $c.m._2$, $c.m._3$ calloso-marginal sulcus.
cing. cingulum.
diag. diagonal sulcus.
ep. epiphysis.
Eb. sulcus of Eberstaller.
for. fornix.
for.(a.p.) precommissural fibres of anterior pillar of fornix.
for.(p.p.) postcommissural fibres of anterior pillar of fornix.
f.M. foramen of Monro.
$f._1$ superior frontal sulcus.
$f._2$ inferior frontal sulcus.
gr.long.fiss. great longitudinal fissure.
gyr.dent. gyrus dentatus.
hyp. hypophysis.
inc.t. incisura temporalis.
in.pa. intraparietal sulcus.
lam.ter. lamina terminalis.
M.B. mid brain.
occ. pars occipitalis.
op.c. optic commissure.
pa.occ. parieto-occipital-fissure.
p.l. post-limbic fissure.
pre.s. superior precentral sulcus.
pre.i. inferior precentral sulcus.
Ro. fissure of Rolando.
ro. rostral sulcus.
$S._1$, $S._2$, $S._3$ fissure of Silvius.
$t._1$ superior temporal sulcus.
$t._2$ inferior temporal sulcus.